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A Summary of Current Program and
Preliminary Report of Progress

TOBACCO RESEARCH

of the

United States Department of Agriculture
and related work of the
State Agricultural Experiment Stations

This progress report is primarily a research tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs. The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C. 20250

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ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

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The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

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The second type of report brings together the USDA program and progress for the following commodities and subjects:

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11 - Sugar
13 - Tobacco

A copy of any of the reports may be requested from Axel L. Andersen, Executive Secretary, Tobacco Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250.

Introduction

This annual report deals with research on all types of tobacco. However, it does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only tobacco problems, but also to the problems of other commodities. Progress on cross-commodity work is found in the organizational unit reports of the several divisions.

The report covers Farm Research; Nutrition, Consumer, and Industrial Use Research; and Marketing and Economic Research. As shown in the table of contents, there is a breakdown of the research program by problem areas.

For each area, there is a statement of (1) the Problem, (2) USDA and Cooperative Program, (3) Program of State Experiment Stations, (4) a summary of Progress during the past year on USDA and Cooperative Programs, and (5) a list of Publications resulting from USDA and Cooperative Programs.

Research on tobacco crops is supported by (1) Federal funds appropriated to the research agencies of the U. S. Department of Agriculture, (2) Federal and State funds appropriated to the ten State Agricultural Experiment Stations and Puerto Rico, and (3) private funds allotted to research carried on in private laboratories or to support of State Station or USDA work.

Research by U.S.D.A.

Farm Research in the Agricultural Research Service comprises investigations on breeding and genetics, culture, variety evaluation, diseases, insects, and crop harvesting, handling operations and equipment, and curing. It is carried out in the following divisions: Crops, Entomology, and Agricultural Engineering. The work involves 64.1 professional man-years of scientific effort.

Nutrition, Consumer and Industrial Use Research in the Agricultural Research Service deals with the chemical and physical properties of tobacco leaf and the chemical composition of smoke. This work is done at the Eastern Utilization Research and Development Division, at Wyndmoor, Pennsylvania. The work involves 17.5 professional man-years of scientific effort.

Marketing and Economic Research is done in two services. Marketing research in the Agricultural Research Service deals with the physical and biological aspects of assembly, packaging, transporting, storing, and distribution from the time the product leaves the farm until it reaches the ultimate consumer. Economic research conducted in the Economic Research Service deals with market structure, practices and competition; product quality; margins, costs, and efficiency; supply and demand; and outlook and situation. The work reported herein is done by the following divisions: Market Quality Research and Transportation and Facilities Research Divisions in ARS, and Marketing Economics and Economics and Statistical Analysis Divisions in ERS. The tobacco research in the marketing and economic research area involves 12.6 professional man-years of scientific effort.

Interrelationships Among Department, State and Private Research

A large part of the Department's research is cooperative with the State Experiment Stations. Many Department employees are located at State Stations and use laboratory and office space close to or furnished by the Stations. Cooperative work is jointly planned, frequently with representatives of the producers or industry participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators, which frequently includes resources contributed by interested producers or industry.

Research is in progress on all domestic tobacco types in the various production areas with especially close cooperative research at 12 agricultural Experiment Stations. A considerable amount of research effort is devoted to breeding and genetics, diseases, quality and varietal investigations, and culture and physiology. Presently the total research program has expanded considerably to include chemical and physiological studies on health-related aspects of tobacco. These studies are being conducted by Eastern Utilization Research, Crops Research, and Market Quality Research Divisions of ARS. Much of the research is under contract.

Close cooperation is also maintained with private industry including cigarette and cigar manufacturers, chemical companies, and machinery manufacturers. All of the tobacco companies conduct vigorous and diverse programs designed to improve the quality of the product and reduce manufacturing costs. These companies are also studying new methods for producing "homogenized tobacco leaf" or "sheet tobacco" for cigarettes or cigar binders or wrappers; development of new tobacco varieties and related organic problems, and chemical composition of leaf and smoke. The tobacco companies' work depends considerably upon discoveries resulting from fundamental work by public agencies.

Research by chemical companies is concerned with the development of new tobacco flavoring agents, cigarette paper and filters, chemicals for agronomic use, "sheet tobacco" process, and new and improved machinery for manufacturing tobacco products. The Department and other public agencies continue to provide much of the basic data needed to carry out these programs.

The manufacturers of chemicals for disease control and plant growth regulation continue to expand their efforts to produce new products and introduce them into use. The Federal Government assists in this area in the evaluation of new plant growth regulators and their effect on quality.

Basic research done by the Department and States will be utilized by industry and other organizations in their research programs, especially in the further development of improved products and equipment. Industry's cooperation in supporting tobacco research at Federal and State Stations has contributed greatly to its success.

Two excellent examples of research accomplishments are the development and release of Burley 49, a multiple disease resistant tobacco variety, by the Crops Research Division, and the effective use of light traps by the Agricultural Engineering Research Division to reduce hornworm moth populations.

Basic and applied research on the genetics of tobacco and its diseases made possible the development of Burley 49, a new variety combining quality and resistance to five major diseases. Black root rot resistance has been obtained for the first time through a complex interspecific cross with a wild relative of tobacco.

The first full-scale test of light traps for insect control was initiated in a 113-square-mile area in North Carolina in 1962. There were 366 traps of special design used to catch tobacco hornworm moths. The results from the past three seasons (1962-64) have been very promising and indicate hornworm moth populations in tobacco can be reduced significantly if electric insect traps are installed at a density of three per square mile over an area of at least 12 miles in diameter.

I. FARM RESEARCH

TOBACCO CULTURE, BREEDING, DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. The production of quality leaf, meeting domestic and export use and economic requirements, is becoming increasingly difficult. New disease-resistant varieties and production practices require exacting management for best yields of quality leaf. High analysis fertilizers, growth regulators, and other chemicals demand caution in their usage in tobacco culture. Long-range planning and employment of best available information by the farmer are in order to maintain usable characters in cured leaf at a profitable production cost.

Smoking and health problems have now been brought into focus before all segments of the tobacco industry as well as the consumer. As a result, the confidence of large segments of the public in the safety of cigarette smoking has been shaken. A coordinated research program directed toward remedial measures has received much attention by Department personnel in 1964.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range program involving both basic and applied research directed toward adapting and improving the tobacco plant and production practices to cope with production hazards, increasing labor costs, mechanization, and changing use requirements.

Research work is in progress on all domestic tobacco types in the various production areas with close cooperation of the Agricultural Experiment Stations in the following States: Connecticut, Florida, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia, and Wisconsin. Cooperation with industry is as follows: Brown & Williamson Tobacco Corporation; Liggett & Myers Tobacco Company; Philip Morris, Inc.; P. Lorillard Company; R. J. Reynolds Tobacco Company; The American Tobacco Company; The Imperial Tobacco Company of Great Britain and Ireland; Bayuk Cigars, Inc.; General Cigar Company, Inc.; Consolidated Cigar Corporation; Cullman Bros., Inc.; American Sumatra Tobacco Corporation; and Cigar Manufacturers Association of America, Inc.

The Federal scientific effort devoted to research in this area totals 45.4 professional man-years. Of this number, 8.1 are devoted to breeding and genetics; 8.9 to diseases; 12.0 to quality and variety evaluation; and 16.4 to culture-physiology.

No lines of work were terminated during the reporting period.

PROGRAM OF STATE EXPERIMENT STATIONS

Scientists of the State Experiment Stations are engaged in basic and applied research in plant breeding and genetics, plant pathology, plant physiology, agronomy, and chemistry. In many of the States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of tobacco production.

The cultural and management studies on tobacco include management of seed beds, growing the crop, harvesting it, and curing the leaf. The use of fumigants, rates of fertilizers, irrigation, rotation, spacing, topping, and control of suckers are being evaluated for their effects on yield and smoking quality. Various harvesting and curing techniques are being explored. Some of them are associated with mechanized harvest of tobacco.

The major emphasis in breeding is for improved resistance to diseases such as blue mold, black shank, wildfire, root rot, and mosaic. In some instances interspecific crosses are being used to obtain the desired factors for disease resistance. Resistance to nematodes is also necessary to meet the root-rot-nematode complex. Other objectives of breeding are yield, smoking quality, and specific levels of nicotine and alkaloid content. The nature of heritable variation of tobacco is being studied to determine the relative efficiency of alternative breeding procedures. Other genetic studies concern abnormalities, comparative cytogenetics, and genes controlling quality constituents of various Nicotiana species.

More attention is being given to composition of tobacco smoke and to determinations of components of varieties and tobacco subjected to a wide range of management practices. The more basic studies concern objective methods for determining the chemistry of curing, fermentation processes to produce specific types of tobacco leaf, and the identification of components which may have implications in health.

The total research effort on tobacco is approximately 37.8 professional man-years; of which 9.6 is for culture, 17.7 for breeding and genetics, 4.3 for diseases, and 6.2 for variety evaluation.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Breeding

1. Genetic Control of Suckers. Tests at Beltsville indicate that Kentucky 160, a mosaic-resistant, dark air-cured type produces only one sucker per leaf axil. This contrasts with the two or more normally produced by most varieties. Crosses have been made between Kentucky 160 and flue-cured and burley varieties, and seed of the F_2 (segregating) generations have been produced. Very limited observations of the F_1 hybrids indicate that the one-sucker character is dominant and perhaps simply inherited. The primary objective of the research is to transfer the one-sucker character to flue-cured, burley, and other types of tobacco.

2. New Burley Variety. Burley 49, resistant to five major diseases, was released in February 1965 in cooperation with the Tennessee Agricultural Experiment Station. Burley 49 has (a) greater resistance to black root rot than any variety previously released; (b) high levels of resistance to black shank, wildfire, and tobacco mosaic; and (c) a low but useful level of resistance to Fusarium wilt. This is the first variety of any type of tobacco to be developed with the monogenic, dominant resistance to black root rot from Nicotiana debneyi. Burley 49 resembles Burley 37; however, Burley 49 has more closely spaced leaves on a shorter stalk, a more pronounced stand-up growth habit, and requires 3 to 7 days longer to bloom.

3. New Flue-cured Variety. Flue-cured variety NC 2512 was jointly released by the North Carolina Agricultural Experiment Station and the U. S. Department of Agriculture in 1964, and seeds were made available to seedsmen for the 1965 season. NC 2512 possesses resistance to the root-knot nematode, Meloidogyne incognita, is tolerant to brown spot, and moderately resistant to Fusarium wilt. It also has low levels of resistance to black shank and bacterial wilt. The new variety has been shown to have a higher dollar-value per acre than check varieties Hicks or NC 95. Chemical and smoking characteristics were all found to be within an acceptable range for industry.

4. Flue-cured Tobacco Hybrids. A diallel of 10 flue-cured selections resulted in 45 nonreciprocal hybrids which were evaluated for acre yield, acre value, price per hundredweight, percentage nicotine, percentage sugar, and filling value at Oxford, North Carolina. Topped and untopped treatments were also imposed upon the experiment. The results indicated that nicotine content was the only experimental component that was significantly altered by topping. The data further indicated that significant differences among crosses were demonstrable for all characters, except percentage sugar. This indicates the possibility of selecting superior crosses to be used in the breeding program. These data suggest that, since the crosses

responded similarly across the topping treatments, with the exception of nicotine, it should be possible to evaluate all characters other than nicotine in either topped or untopped trials. Eliminating topping in some experimental procedures would result in considerable financial gain.

5. Mosaic Resistance. The N factor for mosaic resistance in flue-cured breeding lines has been consistently associated with a reduction in yield. At Florence, South Carolina, after six backcrosses, the resistant selections yielded on an average of 1660 lbs/acre, and the recurrent parents averaged 1849 lbs/acre. F_1 hybrids which had only one genetic factor for resistance yielded 1790 lbs/acre. This provides evidence that yield depression is definitely related to the N factor and that the effect is cumulative.

6. Reciprocal Burley F_1 Hybrids. Fifty-six F_1 hybrids resulting from reciprocal crosses with eight parental varieties were compared at Waynesville, North Carolina. Measurements of plant height taken at weekly intervals indicated that the 56 hybrids grew an average of 9.5 cm taller than their parents. A diallel analysis showed no cytoplasmic effects. The 325 different hybrids which were produced at Lexington, Kentucky, by crossing 26 burley varieties that were resistant or susceptible to black root rot, wildfire, black shank, or Fusarium wilt, were generally intermediate in disease reaction relative to the parental lines. A lowering of resistance to wildfire in the hybrids could be detected in the greenhouse when the concentration of bacteria in the inoculum was increased.

7. New Source of Male-Sterility. Cytoplasmic male-sterility results from a maternally inherited floral malformation that effectively inhibits pollen formation. At Florence, South Carolina, several morphologically different male-steriles were incorporated into basic flue-cured stocks by backcrossing. The male-sterile flue-cured lines were then compared in terms of yield and quality with the parental or recurrent normal tobacco types Hicks and Coker 187. Some male-steriles caused significant declines in quality while others produced only slight reductions in quality or yield when compared with the fertile controls. Early growth retardation was associated with some male-sterile tobacco types, but this diminution of early growth did not always influence the yield of cured leaf. Seeds of the best male-sterile types combined with Hicks (PDMS-1) and Coker 187 (PDMS-2) were released for use by plant breeders and commercial seedsmen. An advantage of this new source of male-sterility is the protruding stigma making pollination possible without first splitting the corolla.

8. Breeding Maryland Tobacco. Additional emphasis has been placed on Fusarium wilt resistance in the Maryland tobacco breeding program designed to incorporate mosaic, black root rot, and wildfire resistance. Fusarium wilt resistance has been found in Catterton and Wilson backcross breeding lines, with the latter being unexpected. Three of four Wilson lines exceeded the backcross parent in average acre and hundredweight values at

three State locations. One of these lines, having resistance to black root rot from Nicotiana debneyi and also mosaic and wildfire resistance, exceeded Wilson in smoking aroma. When lines segregating for black root rot resistance were inoculated with isolates of Fusarium, a significantly lower than expected number of the surviving plants were homozygous-resistant to black root rot.

9. Improvement of Cigar Tobacco. Selection within 503, a cross between Burley 21 and Havana 501, has continued and resolved itself to the testing of lines 503-5-1-1 and 503-5-3-3. Evaluations of the 503 breeding lines by judges from tobacco companies have been generally favorable. On the basis of rated points, 503 obtained 101, while the standard variety rated only 53 points. Several breeding lines resulting from crosses of Cuban and Wisconsin Havana and Cuban and Pennsylvania filler tobacco are being studied at Madison, Wisconsin, and Landisville, Pennsylvania, respectively. Tobacco companies are cooperating to evaluate the quality of the cured leaf. Most lines have resistance to wildfire and mosaic as well as yield and quality potential.

10. Dark-fired Tobacco. A fire-cured breeding line, DEX7, has high disease resistance combined with good yield, quality, and type. In variety tests the past two years in Kentucky, it has been equal or superior to Ky 151, a standard variety. The black root rot resistance of DEX7 is from Nicotiana debneyi. DEX7 will be grown experimentally on a large number of farms in 1965 to acquaint growers with its potential.

11. Cytoplasmic Variegation. A mixture of defective proplastids and normal plastids was discovered to cause a type of leaf variegation at Beltsville, Maryland. Segregation of the proplastids from mixtures of defective and normal ones to a condition in which all the proplastids in a cell were of one kind resulted in patches of white tissue (all plastids defective) or areas of green tissue. The variegated condition was seed-transmissible and a portion of the seedlings emerged as variegated. Apparently some fertilization involved megagametophytes which had mixed proplastids, and the mixed condition persisted in the growing point of the developing seedling.

B. Diseases

1. Resistance to Potato Virus Y. The relationship of Potato Virus Y (PVY) isolates from Virginia to other known PVY isolates that cause mottling of tobacco was studied at Beltsville, Maryland. Root knot-resistant lines developed more necrotic symptoms than most root knot-susceptible varieties after inoculation with isolates of PVY. T.I. 1406, a recent introduction from Europe, was a symptomless carrier of PVY after inoculation with all available isolates. A number of tobacco lines secured from Poland, which were reported resistant, developed varying symptoms after inoculation with PVY isolates.

Twenty-six Nicotiana spp. were inoculated with three isolates of Potato Virus Y (PVY) for disease reaction. Many of the species were symptomless in their inoculated leaves, but expressed systemic mottle, veinbanding, and chlorotic spotting. Of the species tested, N. benavidesii, N. bonariensis, N. knightiana, N. paniculata, N. raimondii, and N. suaveolens were rated symptomless 6 weeks after inoculation.

2. Strains of the Wildfire Pathogen. Morphological appearance of the normal isolate of Pseudomonas tabaci and isolates virulent on wildfire-resistant tobacco were similar in comparisons made on nutrient dextrose agar medium or when grown in shake cultures. When grown without shaking on nutrient dextrose broth, the highly virulent isolates produced a heavy pellicle that was difficult to disperse. Colonies streaked on yeast dextrose carbonate agar medium had a corrugated and roughened morphological appearance, whereas normal types produced smooth-edged colonies. Differentiation between the two strains of P. tabaci has not been accomplished by streaking isolates on medium into which various concentrations of 2, 3, 5 triphenyl tetrazoleum chloride were incorporated, although this technique separates virulent from a virulent bacteria causing the bacterial wilt disease of tobacco.

3. Wildfire Resistance. Some Nicotiana spp. resistant to the virulent strain of P. tabaci continue to be highly resistant, but can be altered in reaction behavior slightly by manipulation of inoculum. When inoculated with washed bacterial cells, N. arentsii and N. undulata react by an expression of only the faintest of halo production. If inoculum consists of diluted broth cultures, the reaction is shifted somewhat toward greater formation of halo. The incorporation of small amounts of nutrient broth into the bacterial suspension evidently tends to break down the host's natural resistance.

4. Leaf Spot on Burley. Anthracnose, a potentially serious disease of seedlings, was observed in East Tennessee as localized outbreaks in seed beds which had been wholly or partially flooded by runoff from infested soil. Fungicide treatments applied for control of blue mold were found to give concomitant control of anthracnose. Hybrid derivatives from the interspecific hybrid, 4N(tabacum x nudicaulis) were found to be anthracnose resistant. This result offers the possibility of interspecific breeding transfer of anthracnose resistance.

5. Nematode Resistance. Twenty-five selections of advanced root knot-resistant tobacco breeding lines were evaluated for black shank resistance in the field at Florence, South Carolina. Sixteen selections with PD 406 parentage also possessed potential resistance to bacterial and Fusarium wilts. Moderate to high resistance to black shank was found in six selections, and 10 others had good tolerance to lesion nematodes. Two selections with the PD 406 parentage resistant to black shank and root knot

and producing good yields, were chosen for continuation in regional small plot tests.

Three root knot-resistant tobacco varieties which differed in susceptibility to the lesion nematodes were compared with the susceptible variety Hicks in plots with and without soil fumigation. The fumigated plots were superior in all criteria to nonfumigated. Although affected by both nematodes, Hicks was only slightly more damaged than the other varieties affected by lesion nematodes alone. The root knot-resistant varieties differed in their response to lesion nematodes. Florida 22, one of the root knot-resistant varieties, tolerated a high population of lesion nematodes and produced the highest yield.

6. Field Nematocide Trials. Seven soil fumigants were evaluated in a yield test plot at Florence, South Carolina. Equal control of root knot was obtained by most treatments. Yields of tobacco were increased as much as 187 pounds per acre by soil fumigation. Penphene (tetra-chlorothiophene) was more effective against root knot than lesion nematodes. Experiments in 1964 included the addition of some of the nematocides to transplant water. Penphene at 200 and 400 ppm resulted in reduction of root-knot nematodes, but 800 ppm killed all tobacco plants.

7. Control of Soilborne Diseases. Recurrence of root knot, black shank, and Fusarium wilt was prevented by plant bed management procedures combined with crop rotations and cultural practices on a farm at Tifton, Georgia. The best crop rotation program was not effective unless complete control of the diseases was secured in the plant bed. Methyl bromide and/or Vapam (sodium-N-methyl dithiocarbamate) were effective plant bed sterilants. Crop rotations which were effective for control of root-knot nematodes and Fusarium wilt also were effective against black shank. In this study, 3 or 4 years of Bahia grass sods prevented the recurrence of black shank. A winter cover crop of rye was beneficial to tobacco with respect to yield, price, crop value per acre, and reduced root knot damage. A rye cover crop gave superior results to simple plowing out stubble and fall-fallowing but did not reduce the incidence of black shank.

C. Quality and Varietal Evaluations

1. Quality as Affected by Harvest in Flue-cured Varieties. A significant variety by treatment interaction showed five varieties and breeding lines reacted differently to harvesting treatments when harvested at the normal rate of 1/6 of the leaves each week; 1/3 of the leaves when the second and fifth stalk positions were mature; 1/3 when the third and sixth stalk positions were mature; and 1/2 when the second and fifth stalk positions were mature. Breeding lines NC 4171 and NC 383-5-9 produced best quality and variety Coker 187-Hicks poorest quality leaf. Yields were not significantly altered by these harvesting methods at Oxford, North Carolina.

2. Quality as Related to Curing. Extended yellowing of flue-cured leaf under controlled curing conditions at Oxford, North Carolina, permitted oxidation of sugars to levels approaching that of air-cured leaves. Sugar disappearance was faster in leaves from the bottom and middle stalk positions than it was from the top position. Alkaloids appeared to increase slightly in the early stage of yellowing, then decreased gradually as the yellowing period was extended. As the yellowing period was extended, the color of the cured leaf shifted from yellow to dark brown. Green (immature), ripe (mature), and over-ripe (over-mature), harvestings were made on flue-cured tobacco plants and cured fast, normal, and slow, primarily with respect to the yellowing period. As harvesting was delayed from green to over-ripe, acre yields, percent starches, and total chlorophyll and carotenoid contents and aroma decreased; and the percent reducing sugars increased. As the rate of curing was increased, the percent reducing sugars, starches, and chlorophyll contents decreased; but total carotenoid increased. Normally cured leaf had highest aroma.

3. Variety Response to Suckering Treatments. Variety responses to suckering practices were compared on nine burley varieties at Greeneville, Tennessee, when hand-suckered and when 170 mg maleic hydrazide (MH) per plant were applied after topping. Average yield of all varieties receiving MH was about 300 pounds per acre more than was that for hand-suckered. The highest yielding varieties were Ky. 9, Ky. 10, Ky. 12, and Ky. 16. The lowest yielding variety was Burley 37. Burley 21, HL 21, Ky. 10, and Ky. 12 were the highest in grade quality; Ky. 9, Ky. 10, and Burley 1 were the lowest. Sucker control with MH was only fair in this particular year.

D. Culture and Physiology

1. Plant Bed Covers. Seedling stands at Greeneville, Tennessee, were similar under plastic film and under cheesecloth at the first seeding date but were reduced because of high temperatures under plastic at the second seeding date. Similar losses in plant stands under plastic also occurred at Waynesville and Laurel Springs, North Carolina, because of high temperatures. However, the initial pulling of plants was 19 days earlier under plastic than under cheesecloth for the first seeding at Greeneville, Tennessee, and two pullings had been made before the seedlings under cheesecloth were ready to transplant.

2. Source of Potassium Nitrate in Tobacco Fertilizers. Ammonium nitrate and potassium nitrate were compared as nitrogen sources for burley tobacco at rates of 60 and 120 pounds of N per acre at Greeneville, Tennessee. There were no significant differences in yields of cured tobacco due to rates or sources of nitrogen. However, at the 60-pound rate of N per acre, the tobacco fertilized with ammonium nitrate had significantly better quality than did that fertilized with potassium nitrate.

Substitution of potassium nitrate in varying amounts for ammonium sulfate and sulfate of potash in the fertilizer at Tifton, Georgia, resulted in increased acre yields of cured leaf of flue-cured tobacco ranging from 150 to 300 pounds and price values ranging from $1.75 to $3.25 per 100 pounds. Tobacco company representatives indicated a preference for the cured leaf produced with the higher percentage levels of potassium nitrate. Analytical values of the cured leaf revealed a significant reduction in the sulfur content and a marked increase in burning properties of the leaf grown with the substitution of potassium nitrate for sulfate sources of N and K.

3. Fertilizer Rates for Burley. Varying rates of N, P_2O_5, and K_2O were evaluated for burley tobacco in experiments at six locations in North Carolina for the third year. Increasing the rate of nitrogen from 120 to 220 pounds per acre resulted in increased yields. Quality, as measured by value per hundredweight, decreased with the application of nitrogen in excess of the base rate of 120 pounds per acre. Acre values increased as nitrogen was increased from 120 to 220 pounds per acre. Additional nitrogen above 220 pounds per acre resulted in decreases in acre values. Additional phosphate and potash above the recommended rate of 80 pounds of P_2O_5 and 170 pounds of K_2O, respectively, had varied effects on yields and values among the locations; however, mean results of all locations indicated no response from additions above the recommended rates.

4. Fertilizer Rates for Dark Tobaccos. Dark air-cured and dark fire-cured tobacco yields and values increased sharply with each of the following nitrogen increments: 50, 100, 150, and 200 pounds per acre. On the other hand, there were no yield or value responses in either tobacco type from the following increments of potash: 0, 100, 200, and 300 pounds per acre. Many farmers in Western Kentucky grow both burley and dark tobaccos in the same field and fertilize them the same. Results of these studies show this fertilizer program to be undesirable since burley tobacco has medium nitrogen and high potash requirements; whereas, dark tobaccos have high nitrogen and low potash requirements.

5. Plant Population x N Fertilization for Burley. Burley tobacco plant populations of 7,500, 10,000, and 12,500 per acre fertilized with nitrogen at rates of 75, 150, and 225 pounds per acre were evaluated in two experiments in Tennessee. An additional treatment consisted of 150 pounds of nitrogen and 10 tons of manure per acre. There were no significant differences in yields of tobacco due to population differentials at either location, but significant increases in yields were obtained by using up to 225 pounds of nitrogen at both locations. The yield given by 10 tons of manure plus 150 pounds of nitrogen was similar to that given by 225 pounds of nitrogen alone in each case. At both locations, tobacco grade quality became poorer as the plant population increased; and there was no improvement in quality by using more than 150 pounds of nitrogen.

6. Fertilizer Rates x Irrigation x Sucker Control with Flue-cured Tobacco. Fertilizer rates x irrigation x sucker control were studied in two experiments on flue-cured tobacco at Tifton, Georgia. Four levels of each nutrient were applied per acre: N - 48 to 110 lbs., P_2O_5 - 96 to 192 lbs., and K_2O - 144 to 288 lbs. Normal responses to fertilization occurred in both tests with the maximum yields of the highest quality leaf developing at 70 to 80 pounds of N per acre. Three irrigations made between June 5 and 23, totaling 2.82 inches of water, improved both yield and quality of the cured leaf in comparison with no irrigation; furthermore, irrigation at night was more effective than it was during the day. Compared with hand-suckered plots, the MH-treated plots had substantially higher yields of cured leaf under all treatments. Sucker control with Penar (dimethyl-dodecyl amine acetate) and T-43 (methyl caprate) was somewhat less than it was with MH. Yields from the Penar- and T-43-treated plants were intermediate to hand-suckered and MH-treated plants. Price values per pound of cured leaf generally decreased slightly as the fertilizer rate increased, with the greatest reduction resulting on hand-suckered and Penar-treated plots. Differences in the average price of tobacco among the sucker control treatments appeared nonsignificant. Chemical analyses of the upper primings showed that the percentage total nitrogen and total alkaloids increased as the fertilizer rate was increased, and they were generally highest in hand-suckered tobacco and lowest in MH-30-treated tobacco, with the Penar- and T-43-treated leaves being somewhat intermediate. The reducing sugar content generally followed a trend opposite to that of the nitrogen and alkaloids.

7. Liming for Burley. Lime at 2 tons per acre increased significantly acre yields of burley tobacco at Greeneville, Tennessee. Additional yield responses were not obtained with 4- and 6-ton rates. Average grade quality and acre values were similar for all lime treatments. Three hundred pounds of potash per acre gave highly significant increases in yield, quality, and acre value of tobacco over the no-potash treatments. In a similar test in middle Tennessee, burley tobacco did not respond to liming at rates up to eight tons per acre. On the other hand, significant improvements in yield, visual quality, and acre value were obtained by applying 400 pounds per acre of K_2O in comparison with 100 pounds. At Campbellsville and Princeton, Kentucky, Burley 21 and Ky. 42 tobaccos did not respond to liming at rates ranging up to eight tons per acre.

Several of the recently developed varieties of tobacco tend to show Ca deficiency symptoms in the later stages of growth. Preliminary experiments with plants in growth chambers at Lexington, Kentucky, indicated the effects of temperature. Plants grown at 24° C. showed no Ca deficiency, but susceptible varieties developed severe Ca deficiency symptoms when grown at 30° C.

8. Rotation Studies, Cigar-Filler Tobacco. Crop rotation studies were started in 1956 at Landisville, Pennsylvania, to evaluate effects of various crops in a 4-year rotation on the yield and quality of cigar-filler tobacco. Four rotations in one series included (1) tobacco, wheat, hay, corn; (2) same as (1) except sulfate of potash is used on all crops instead of on tobacco only; (3) tobacco, 2 years of clover-bluegrass sod, corn; and (4) tobacco, 2 years of all-grass sod, corn. All potash applied to rotations (3) and (4) was the sulfate form as in rotation (2). No significant differences in yield between the four rotations were found in 1964 or previous years. The first rotation which is the standard rotation produced the best quality in 1963, but differences in quality have not been consistent.

9. Herbicides for Weed Control. Effective control of weeds at Tifton, Georgia,was obtained by pretransplant application of Trifluralin (alpha, alpha, alpha-trifluoro-2, 6 dinitro-N, N-dipropyl-p-toluidine) incorporated into the soil followed by post-transplant surface application of Diphenamid (N, N-dimethyl-2, 2-diphenylacetamide). Tillam (propyl ethyl-n-butylthiol-carbamate) incorporated into the soil gave about the same weed control as Trifluralin-Diphenamid, with ironweed showing resistance to both treatments. Best control resulted with the Vernam-incorporated treatment. Except for some possible early minor injury from Trifluralin, there was no apparent injury to tobacco from the herbicides used.

Various rates of Trifluralin-Diphenamid combinations failed to control weeds in burley tobacco at Greeneville, Tennessee. A duplicate test was planted in which all treatments, including those chemically treated, were kept weed-free by conventional cultivation. The average yield of the chemically treated plots tended to be lower than the yield for the cultivated treatment.

10. Management of Frost-Injured Burley in the Fall. Killing frost (24° to 27° F.) first occurred in Western North Carolina on the night of October 7 and continued for five consecutive nights. Tobacco harvested at 0, 3, 6, 9, and 12 days following initial frost exhibited typical and severe frost injury at Waynesville and Laurel Springs, North Carolina, except in the protected treatment. In all tests, the acre yields of cured leaf increased progressively through the sixth day following the initial frost injury; and the yields were higher than that from the protected treatment. After the sixth day, yields dropped sharply and progressively through the 12th day and were lower than the control. The yield increases through the sixth day appeared to be associated with an increase in hydroscopicity of leaf tissues. Lowered yields after the sixth day apparently resulted from leaf deterioration and loss in the field. Injury to the tobacco from frost was so severe in all tests that a grade x price evaluation could only be estimated, but the value appeared to be reduced by 50 to 75 percent in comparison with the control.

11. Use of Supplemental Gas Heat in Curing Burley. The use of supplemental gas heat increased yield by about 150 pounds per acre over the nonheated control in curing studies with burley tobacco at Greeneville, Tennessee. There was also a tendency toward improvement in leaf quality by the use of heat.

12. Relation of Harvest to Curing of Flue-cured Tobacco. The potential for deviation from conventional harvests of normally topped tobacco at Oxford, North Carolina,was limited to removal of no more than one-half the leaves at one time. Optimum maturity at harvest was important in maintaining satisfactory yield and use value as number of leaves removed per priming was increased. Removal of all the leaves at one harvest resulted in unsatisfactory yield and quality. In topping tests plants were decapitated at the time the specified leaf number was formed. Yield of cured leaf was reduced sharply as height of topping was reduced from 18 to six leaves, although primary suckers were allowed to grow for leaf production. Lower leaves of plants topped to six and nine leaves were thick and fleshy and cured to excellent quality, resembling mid plant leaves from normally topped plants.

13. Tobacco Seed Germination. The interaction of light and tobacco seed germination was studied at Lexington, Kentucky, using seed which require light and seed which germinate in darkness. Within the dark-germinating seed,the percent germination was lower at constant 30° than it was at constant 20° C. Irradiation with red light promoted germination of the light-requiring seeds, and the action of red was reversed by far-red light. The reversal, however, was more complete at 30° than at 20° C.

14. Plant Growth Regulator - Indole-3-Acetic-Acid. A new concept that Indole-3-Acetic-Acid (IAA) needs to be oxidatively transformed into an active form was tested at Tifton, Georgia. With a model system using commercially available Horse-Radish Peroxidase (HRP) enzyme, the rate of oxidation of IAA was determined spectrophotometrically by following the rate of change of absorption at 250 mμ and 290 mμ. Isolation and partial purification of IAA oxidizing enzymes from rapidly dividing cells of Maryland tobacco tissue showed co-factor requirements as well as the products formed to be very similar to those required by commercial HRP enzymes. However, pH 3.0 was optimum for the isolated enzyme;whereas, pH 6.1 was optimum for the commercial HRP. The effects of various known growth regulants upon the oxidation of IAA of HRP enzymes were tested. The growth inhibitors maleic hydrazide and aza-uracil reduced the oxidation of IAA. Iodoacetic acid promoted the IAA oxidase when IAA concentrations were low, but inhibited oxidation at high IAA levels.

15. Plant Growth Regulators - Aza-uracil and Aza-uridine. Results at Beltsville, Maryland, showed that aza-uracil and aza-uridine effectively inhibit tissue cultures of tobacco as well as sucker growth on intact

plants. The aza-compounds are readily reversible with uracil and uridine in tissue culture, but this is not true for the control of suckers on plants. Maleic hydrazide also inhibits the growth of tissue culture, but the inhibitory effect cannot be reversed by uracil and uridine. This suggests a basic difference in the mechanism of action between maleic hydrazide and aza-uracil.

Aza-uracil inhibits in a competitive manner the oxidation of IAA by commercial HRP as well as peroxidases isolated and partially purified from tobacco. The effect of these analogues of nucleic acid constituents is of fundamental interest.

16. Plant Growth Regulators - Fatty Acids. C-10 fatty alcohols gave the highest degree of sucker suppression out of more than 20 fatty alcohols and related compounds of various carbon chain lengths included in initial greenhouse and field screening tests. Results were analogous to fatty acid tests on all types of tobacco in which C-10 material gave best control. In the second phase of evaluation, out of 12 materials tested in the field on all domestic types of tobacco, two were qualified for further testing. However, there was an interaction between materials and tobacco types with burley being the most sensitive to chemicals. Three chemicals--methyl caprate, Penar, and the potassium salt of maleic hydrazide (KMH)--responded differently in advanced regional tests with respect to field performance and chemical, physical, or smoking properties of cured leaf. Performance of methyl caprate in these extensive tests was such as to warrant further evaluation of this fatty acid derivative on all types of tobacco, while further evaluation of Penar is limited to flue-cured and KMH to burley types.

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TOBACCO INSECTS

Entomology Research Division, ARS

Problem. Insecticides that effectively control insects that attack tobacco, particularly budworms, hornworms, flea beetles, and aphids, have resulted in undesirable residues on cured tobacco. Such residues adhere to the leaf through commercial processing into cigarettes and some have been found in the main-stream of smoke from commercial cigarettes. Methods for controlling insect pests of tobacco that will not lead to insecticide residues in cigarettes or other manufactured tobacco products are urgently needed. Research on lures, light traps, sterilization techniques, other new approaches to control, and better utilization of predators, parasites, and diseases of tobacco insects should receive more attention. Studies to find market-acceptable tobacco varieties that resist insect attack and to develop environment-compatible insecticides that leave no undesirable residues are equally important.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic and applied research on tobacco insects to develop effective control methods for tobacco insects that will alleviate the residue problem on the harvested leaf. The research is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway and with the tobacco industry. Studies are conducted at Oxford, N. C., Florence, S. C., Quincy, Fla., and at a temporary location on St. Croix, Virgin Islands, as a satellite of Oxford. Contract research supported by the Department is in progress at the Kentucky, North Carolina, and South Carolina Agricultural Experiment Stations, and the Virginia Polytechnic Institute. A grant for studies on tobacco insects at the Clemson Agricultural Experiment Station in South Carolina has been implemented.

The Federal scientific effort devoted to research in this area totals 7.5 professional man-years. Of this number, 1.4 is devoted to basic biology, physiology, and nutrition; 1.1 to insecticidal and cultural control; 0.2 to insecticide residue determinations; 0.2 to biological control; 4.0 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; and 0.5 to program leadership.

In addition Federal support of research under contracts and grants provides 3.1 man-years in this area. Of this total 1.2 is devoted to basic biology, physiology, and nutrition and 1.9 to insect sterility, attractants and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

The tobacco-producing states have an active research program on tobacco insects and their control.

Biological research places emphasis on seasonal history and behavior of injurious insects. Much of this work consists of evaluating the effects of environmental conditions throughout the year on population dynamics and rearing the insects in the field and laboratory. For example, in the tobacco hornworm the winter survival, length of life and factors inducing and terminating diapause are being studied. The accumulation of data on abundance and its relation to climatic factors may make it possible to predict the severity of infestations of this insect.

New insecticides, particularly those believed to be heat degraded or metabolized,are being screened to determine their efficiency in controlling tobacco insects. Those materials which appear to be biologically promising are placed in advanced testing programs. Coincidentally, the fate of the residue from application through curing, ageing, and smoking is studied. New application methods, particularly those which might decrease residues, are evaluated. Attempts are being made to utilize parasites, predators, and disease organisms more effectively. Cultural controls under investigation include influences of crop rotation and fertilizer application on the kinds and numbers of insect pests that attract tobacco.

Research is in progress to isolate the female attractant from the hornworm moth and use it or other baits to lure the moths to traps.

Plant resistance studies entailing screening of varieties and foreign introduction are being conducted to locate factors conferring resistance to specific pests. Susceptibility to infestation is measured by comparing the reproduction of the pest involved on each variety, the relative tolerance of the plants to insect attack and general agronomic characteristics. Where resistance is observed, backcrosses and selections are made to convey the responsible factor to adapted varieties. Biochemical studies are performed to determine the chemical nature of the factor and its influence on the pest involved.

There are 10.6 professional man-years dedicated to research on tobacco insects by the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

Studies at Florence, S. C., during the past few years have shown that moths from overwintering tobacco hornworm pupae do not emerge as a spring brood. Instead, they begin to emerge the latter part of May and continue to emerge until around July 23.

At Quincy, Fla., light trap catches of the tobacco budworm were 24% higher than for the corn earworm April 26 through June 1, 1965.

Hornworm populations on St. Croix, U. S. Virgin Islands, based on a single

status trap, were extremely low during November 1964 through March 1965 due to a severe drouth. However, within 4 days after heavy rainfall, trap catches increased to previous levels. In March 1965, 8 additional traps were installed throughout the entire Island. Surprisingly, high catches were taken in the eastern portion of the Island which tends to be drier and with fewer host plants than other parts of the Island. However, the narrowness of the eastern portion may tend to increase the catch by channeling moths within the vicinity of the trap. Reciprocal crosses between St. Croix and North Carolina male and female hornworms were successful in producing progeny.

B. Insecticidal and Cultural Control

At Florence, S. C., a special tractor attachment for the application of insecticide granules as a row treatment for the control of wireworms resistant to chlorinated hydrocarbon insecticides was evaluated. Further cooperative studies with plant pathologists of the Crops Research Division indicated chemicals for the control of wireworms and nematodes may be combined in a single application. A new insecticide, Niagara 10242 (ENT-27164), applied to the soil in granular form for wireworm control, appears to be an efficient systemic material for the control of the tobacco flea beetle, the tobacco hornworm, and the tobacco budworm. Counts of injured plants 6 weeks after transplanting indicated good protection against all three insect species where the insecticide had been applied at rates of 4 and 6 pounds of active ingredient per acre. These application rates also gave good wireworm control.

The cabbage looper is becoming increasingly important as a pest of tobacco in South Carolina and was especially severe in 1965. By the middle of June, populations in some tobacco fields in the Florence, S. C., area were the highest on record. In one 4-acre field under observation, the loopers appeared early and continued to increase in numbers despite 8 applications of insecticides for their control.

At Quincy, Fla., the practice of applying chlorinated hydrocarbon insecticides plus parathion once or twice each week to shade tobacco has resulted in high residues on the wrapper leaf of cigars. To explore alternate methods of control that would result in lower residues, granular Di-Syston was applied to the soil as a preplant treatment at varying dosages for aphid control. The shade was then planted with insect-free plants. All levels of Di-Syston tested gave good control for about 6 weeks, whereas the check plots were destroyed by aphids in about 4 weeks. Four light traps were placed outside of the shade and one in the center. Tobacco budworm and cabbage looper damage was light.

C. Insecticide Residue Determinations

In 1963, representative samples of tobacco were obtained from 8 warehouses in North Carolina. Analysis showed the presence of DDT ranging from 3.3

to 12.0 ppm, TDE from 0 to 28.0 ppm, and endrin from less than 0.5 to 2.3 ppm. Residues found in samples of shade tobacco from growers' stocks in the Quincy, Fla., area contained 300 ppm of DDT, 0 TDE, and 13.7 endrin. Samples from 2 experimental plots of shade grown tobacco not treated with chlorinated hydrocarbon insecticides showed the presence of DDT and endrin in amounts that indicate possible translocation or contamination from the soil or contamination from some other source.

D. Biological Control

At Quincy, Fla., green lacewing eggs were placed on shade tobacco plants infested with the green peach aphid. The hatching lacewing larvae, however, were not adaptable to the highly pubescent surface of the tobacco leaves and failed to become established.

In the Oxford, N. C., light trap area, only 1 out of 24 untreated check plots showed hornworm or budworm counts justifying the use of insecticides. However, treatment was delayed several days and parasites and predators effectively eliminated the infestation.

E. Insect Sterility, Attractants, and Other New Approaches to Control

At Oxford, N. C., studies were conducted in 1963 and 1964 to determine the effectiveness of light traps for large-area control of the tobacco hornworm. Results in 1963 showed an 83% reduction in numbers of eggs and small larvae at the center of the 113-square-mile study area as compared with infestations 6 miles outside the area. In 1964 hornworm damage estimates indicated reduction of 89% at the center of the trapping area as compared with conditions 20 miles outside the area. Marked increases in stalk destruction in the trap area in the fall of 1962 and 1963 probably contributed to the resulting control. In 1963 the number of insecticide applications by individual growers for hornworm control inside the trap area was reduced about 90% and in 1964 applications for control of all tobacco insects were reduced by about 55% as compared with applications outside the area. Observations on tobacco budworm populations also indicated some control of this insect in the light-trap area. In 1964 the percent reduction in budworm-damaged plants in the center of the light-trap area, as compared to 6 miles outside the area, was about 57% on untreated tobacco fields. There were also some indications that light traps reduced the corn earworm populations.

At Quincy, Fla., light traps were placed around and inside a 7-acre shade of cigar wrapper tobacco. Twelve traps with four 32-watt circline lamps were placed about 50 feet from the shade on all 4 sides and spaced 160 feet apart. Five omni-directional traps with fan were placed inside the shade, one in each corner and one in the center. Di-Syston was applied in the drill at 4 pounds per acre at transplanting time for aphid and flea beetle control. Subsequent treatments were one application of insecticide for flea beetles and in replicated plots in the field one application of

polyhedrosis virus alone, Bacillus thuringiensis alone, and a combination of the two pathogens at 1/2 the usual dosage for tobacco budworms. Budworms collected from each treatment indicated that B. thuringiensis was the better and faster acting pathogen, although the virus gave a 60% kill of collected larvae. The combination of the two agents gave the lowest kill. In this 7-acre shade with light traps only 2 insecticide applications were made for all insects compared with 17 applications in a 10-acre shade area without light traps. The percent leaves damaged by budworms and the cabbage looper ranged from 0.5 to 2.7 in the light-trap shade compared with 1.0 to 3.5 in the shade without light traps.

At Florence, S. C., 3-day old virgin tobacco hornworm females were better sources for extracting sex attractant than younger females. This was also confirmed at Oxford when 2- to 4-day old virgin females showed greatest attraction to males when used in combination with light traps.

At Oxford, N. C., virgin female hornworm moths placed near light traps greatly increased the catch of male hornworms. For every 94 male moths caught by the light trap alone, the addition of each female up to 10 increased the male catch by 89.

In a cooperative test with the Agricultural Engineering Research Division, 3 light traps per square mile are being established on the Island of St. Croix to test the feasibility of total population control of the tobacco hornworm.

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TOBACCO HARVESTING, CURING, AND INSECT CONTROL USING LIGHT TRAPS

Agricultural Engineering Research Division, ARS

Problem. The development of equipment and methods for efficiently harvesting and farm handling tobacco with emphasis on the preservation of the inherent qualities of the tobacco during these processes, is necessary if the farmer in the United States is to compete effectively on both the domestic and foreign markets.

There is need to develop better methods, techniques, and equipment for use on farms in preparing tobacco leaf for market so as to preserve quality, and to prevent spoilage and damage from mechanical handling. The basic underlying principles that pertain to the curing and sorting of tobacco need to be determined.

To minimize the use of possibly hazardous chemicals as much as possible, there is need for continued research on nonchemical methods for insect control. Further evaluation of electrical methods, alone or in combination with insecticides, chemosterilants, and biological attractants, is necessary.

USDA AND COOPERATIVE

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling, on farm processing methods, and on insect control. Tobacco harvesting and handling, and curing and storing research is cooperative with the Experiment Station at Lexington, Kentucky. Investigation on electrical and physical methods of tobacco insect control are conducted in North Carolina, South Carolina, Kentucky, and Virginia.

The engineering effort devoted to research in the area of tobaccc harvesting and handling is 2.0 professional man-years; curing, 2.0 professional man-years;and 2.6 professional man-years are devoted to investigations on the use of light traps for tobacco insects.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Several of the State Agricultural Experiment Stations are engaged in some aspect of basic or applied research concerned with improving machines and methods for efficient harvesting, farm handling, and curing of tobacco; and with using various electrical methods for the control of tobacco insects. Much of the research is cooperative with the Department.

REPORT OF PROGRESS FOR USDA
AND COOPERATIVE PROGRAMS

A. Tobacco Harvesting Equipment

1. Handling of stalk-cut air-cured tobacco on portable curing frames. This study is being conducted at a research tobacco curing barn with a clear-span pole structure furnished by the University of Kentucky Experiment Station. Both wood and steel portable frames have been handled at the field and barn with a front-loader tractor. Stalk-cut tobacco was placed in the portable frames at bulk densities varying from 24 to 48 square inches per stalk in plan area. The levels of bulk density had no significant effect upon curing based upon government graders' evaluation. Labor requirements of 15 to 20 man-hours per acre for this housing procedure correspond to 40 man-hours per acre required for conventional practice. Objectives of further research are (1) continue study of labor and equipment performance, (2) determine effect of prolonged wilting of tobacco on the frames prior to housing, and (3) determine environmental characteristics and quality of cure resulting from variation of housing procedure.

Handling of stalk-cut air-cured tobacco on vertically suspended strings. A system is proposed utilizing a tobacco harvester having the function to fasten the base of cut tobacco to continuous twine. The "chain" of stalks is to be conveyed to a wagon drawn by the tractor-attached harvester. A portable drum-hoist at the top of a modified conventional air-cure barn will be used to pull the tobacco from the wagon. Control and power circuits for hydraulic or hydraulic and pneumatic harvester components have been designed. Curing tests have indicated satisfactory air-cure using the proposed procedure of handling.

Burley tobacco stalk strength properties. The objective of this work is to determine the plant's response to external forces which may be exerted by machines used to handle the crop. Three aspects of stalk strength were investigated: (1) Resistance of the stalk to crushing forces perpendicular to the long axis; (2) the distance a split in the stalk will progress; and (3) flexure tests to determine the flexure modulus of elasticity.

Results: (1) The mean force resisted at the base of the stalk was 314 lbs. when using crushing jaws 1/2-inch wide, and 354 lbs. with jaws 1/4-inch wide. This difference was not statistically significant at 5 percent level. Similar results were obtained when the forces were applied 4 inches from the base of the stalks. There were significant differences among the three testing dates which were 1 week apart due to a decrease in resistance with maturity.

(2) The stalks in this investigation were split initially at the base, the stalk haves were separated laterally a distance of 4 inches, and the distance a 1-inch x 1-inch block could be inserted into the split was measured. The mean distance of insertion ranged from 10.2 inches the first week of testing to 11.1 inches for the third week. Though these values increased slightly with maturity they were not significantly different.

(3) Flexure modulus of elasticity of stalk material was determined for small clear specimens excised from the woody portion of the stalk. These specimens were tested in flexure in a manner similar to ASTM specifications for wood except on a reduced scale (7/32-inch x 7/32-inch x 3 1/16-inch test span). Similar tests were also made on sections of intact stalk from the same stalks to check the applicability of the values to intact stalks. The flexure modulus of elasticity of the stalk material was determined to be 406,000 p.s.i. for the mean of 40 specimens from 20 stalks with a standard deviation of 76,400 p.s.i. The mean modulus of elasticity determined from the intact specimens, assuming them to be of uniform cross-section over the test span, was 396,000 p.s.i. with a standard deviation of 85,300 p.s.i.

Development of a mechanical burley tobacco harvester. Field tests of the spiral-held spear were conducted in an effort to determine: (1) Leaf loss as affected by height of spearing and ground speed; (2) leaf loss as related to the point of contact of the leaves with the spearing mechanism; (3) leaf loss as affected by leaf-parting devices (powered and stationary); and (4) power requirements of the spearing unit.

Results: (1) The total number of leaves lost per plant ranged from a mean of 0.94 at 0.56 m.p.h. and a spearing height of 10 inches, to a maximum of 2.69 at 0.56 m.p.h. and a spearing height of 16 inches. The difference due to different ground speeds was not statistically significant; however, the difference due to different spearing heights was significant.

(2) Greatest leaf loss was found to be below a point 2 inches below the spear point. Guides for centering the stalks onto the spear point were in this area and contributed to this loss of leaves.

(3) No significant difference was found between four types of leaf-parting devices.

(4) Power requirements of the spearing mechanism ranged from a minimum of 0.59 hp. to a maximum of 0.84 hp.

B. Tobacco Curing

1. Thermal conductivity and specific heat of burley tobacco during the cure. These basic engineering properties were determined for post-harvest conditions, from the turgid state through the curing process. Mathematical expressions for these leaf properties as functions of moisture content and density were derived. The findings were in agreement with basic heat theory for solid materials. There are no plans to continue this line of research.

Mass and energy balance of burley tobacco during the cure. In burley tobacco mechanization, the continuing search for new and improved methods of harvesting and curing has brought about the need for a thorough understanding of the curing process. Any process involving the heating or cooling of a biological material requires a thorough knowledge of its thermal properties before a mass and energy balance can be written for the process.

The lack of information reported in the literature and the potentials of applying this mass and energy balance to a controlled environment tobacco curing system has prompted this study with the objective being to write a mass and energy balance for the curing process. A thorough search of the literature revealed the mass and energy balance to be affected by the following: Temperature, humidity, air flow, density, oxygen and carbon dioxide concentrations as well as the stage of cure. A respiration chamber has been designed to give a continuous measurement of the heat produced, carbon dioxide and water evolved, oxygen consumed, total weight loss and air flow. Chamber conditions will be maintained at various levels of temperature and humidity within the curing range of burley tobacco. The future plans include construction of the chamber and conducting tests, with both field- and greenhouse-grown tobacco, on the entire plant, or on leaves or stalks for determining the respiration heat in order to write a mass and energy balance for the curing process.

Measuring the coloring rates of primed burley leaves with time-lapse photography. Basic information concerning the influence of temperature, humidity and air flow on the curing rate of primed leaves is needed in the design of curing systems which will enhance the usability of the end product. The objective of this study was to determine the coloring rates and drying rates of selected leaves as a function of these three environmental factors. From a series of 84 observations, equations were developed which give the relative importance of each environmental factor. It is significant to note that while the coloring rate is significantly influenced by all three environmental factors, the drying rate is significantly influenced by the specific humidity deficit only. This work is essentially completed and the results will be summarized for a technical publication.

Development of a 2-week curing cycle for primed burley tobacco. Past experience with bulk curing of primed burley indicated a need for a longer curing schedule than 1 week. The objective of the present work was to determine the acceptable levels of humidity for curing primed burley at constant temperature and air flow conditions. The tests were conducted at biweekly intervals on leaves which were primed from the upper half of the plant. Humidity treatments were 60, 70, and 80 percent r.h. (relative humidity). A standard schedule consisted of 90° F., 50 percent r.h. for 1 day; then 2 replications at each of the 3 humidity levels (60, 70, and 80 percent) for 11 days; followed by 150° F., 20 percent r.h. for 1 day for final drying; and 80° F., 87 percent r.h. for 1 day for "casing" the tobacco. These treatments were repeated for three primings. Judgments based on government grades and current price supports indicated differences in value only between primings, with the value per pound for the last priming being significantly lower. However, visual observations indicated the high humidity treatment to be superior for producing an acceptable color in the cured tobacco.

This work will be continued with the objective of measuring the progress of the cure by assaying certain chemical constituents in the leaf for the purpose of judging the progress of the cure. Comparisons will be based on malic and citric acid contents of both primed and unprimed leaves.

C. Electric Traps for Tobacco Insects

Research on use of light traps for attracting and controlling tobacco insects was continued at Blacksburg, Virginia in cooperation with the Virginia Agricultural Experiment Station, and at Oxford, North Carolina in cooperation with the Entomology Research Division, ARS, and the North Carolina Agricultural Experiment Station. A new project was also established late in the year at Lexington, Kentucky, where cooperative studies will be conducted with the Kentucky Agricultural Experiment Station.

Investigations on the effectiveness of insect light traps covering large areas for the control of tobacco insect populations were continued during 1964 at Oxford, North Carolina. The circular area covered by traps was increased from a 6-mile radius (113 sq. miles) with 366 traps to a 10-mile radius (314 sq. miles) with 1,079 traps. Gravity-type traps with blacklight lamp attractants at a density of approximately three per square mile were installed in the 200-square-mile annular area around the original circular area. Gravity-type traps in the inner 50-square-mile circular area (4-mile radius) were replaced with fan-type traps at a density of about 5.5 traps per square mile. The change in trap type and increase in trap density were made to study possibilities of controlling insects with smaller wingspread than that of the hornworm moth. Check traps were extended to 20 miles from the center of the area in north, south, east, and west directions. Installation of traps was not completed until mid-August.

The mean catch per trap, hornworm damage to tobacco, the number of hornworm eggs laid on tobacco, and the number of budworm larvae on tobacco plants were lowest at the center of the trapped area and increased as the distance from center increased. The estimated reduction in hornworm population between 12 miles from the center and the center was 77 and 75 percent for males and females, respectively, as compared to 94 and 64 percent, respectively, in 1963. The estimated population reduction between 20 miles from center and the center was 89 percent for both sexes. The reduction in plants damaged by budworms in the untreated tobacco fields between 12 miles from the center and the center was 57 percent in 1964.

Inconclusive results were obtained from farmer cooperative area control investigations in cooperation with the South Carolina and Kentucky Agricultural Experiment Stations. Lack of sufficient area coverage or desired trap functioning may have influenced results.

At Chatham, Virginia, field investigations were continued to determine the time of night during which insects are most active. Some indications were obtained that the activity is greatest during early evening hours. For moths, in general the activity increased again prior to dawn. An observation was made that insects considered to be nocturnal were captured in light traps during daylight hours with lamps energized.

At Blacksburg, Virginia, encouraging results have been obtained from preliminary electrophysiological studies on tobacco hornworm moths. This work will be intensified in an effort to determine the characteristics of the radiant energy that are most attractive or repulsive to tobacco insects.

Plans for the 1965 season include studies to improve trap design, extension of check traps to 30 miles from the center in the Oxford experiment, tobacco insect migration studies near Cape Hatteras, North Carolina, shade-tobacco insect control studies in Quincy, Florida, and area population control investigations on St. Croix, Virgin Islands, all in cooperation with Entomology Research Division, ARS.

St. Croix will be used by Entomology and Agricultural Engineering Research Divisions as an isolated field laboratory for testing effectiveness of electric insect traps and other insect control measures.

During the past year, approximately 2.6 PMY were devoted to these projects since new men were added during the year. With the addition of a man on St. Croix, this will be increased to 4 PMY.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Tobacco Harvesting Equipment

None.

Tobacco Curing

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Henson, W. H., Jr., and Hassler, F. J. 1964. Certain dielectric and physical properties of cured tobacco leaves. Humidity and Moisture, Vol. 11, Ch. 20, pp. 148-160.

Young, J. H., Bunn, J. M., and Henson, W. H., Jr. 1964. Humidity and moisture problems associated with the handling and storage of cured tobacco. Humidity and Moisture, Vol. 11, Ch. 29, pp. 231-238.

Electric Traps for Tobacco Insects

Stanley, J. M., Lawson, F. R., and Gentry, C. R.. 1964. Area control of tobacco insects with blacklight radiation. Transactions of the ASAE. 7(2):125-127.

II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

COMPOSITION AND PROCESSING

Eastern Utilization Research and Development Division, ARS

Problem. Although neither food nor fiber, tobacco nevertheless is grown on about a million acres, and in seven states provided more farm cash receipts than any other field crop in 1964. The farm value is about $1.3 billion. This crop is unique in that it yields about $3.1 billion in Federal and State taxes. Of the problems affecting the tobacco industry, the much publicized charges concerning the effect of tobacco usage on health are the most serious. Although much controversy still surrounds these charges, the importance of the tobacco economy and the seriousness of the charges dictate that research in this area be intensified. Such a program will serve to elucidate more completely the extent of smoking-health relationships and the capabilities of research to alter the observed physiological effects of smoke on animal tissue. Information obtained in such studies may also be of value in other industrial problems, such as the determination of relationships between the chemical composition of tobacco and smoke, and the overall quality of tobacco products. It should be noted that the present program represents a significant reorientation of effort from past endeavor concerned mainly with quality problems.

USDA AND COOPERATIVE PROGRAM

The Department has an expanding program involving many facets of the chemistry and biology of tobacco and its smoke. Much of the work is basic in nature and, although the program is health oriented, many findings of value in industrial problems not related to health may be forthcoming. The present program is divided into five general areas: Basic studies on the composition of cigarette smoke; similar investigations on tobacco leaf; the nature of the pyrolytic products from leaf substances or fractions; the effect of chemical additives on the composition of cigarette smoke; and biomedical studies related to the biological assaying of cigarette smoke.

As a result of a special Congressional appropriation, a substantial part of the present utilization research program will be performed at the University of Kentucky, Lexington, Kentucky, under several contracts and a cooperative agreement.

The Federal work is conducted at Wyndmoor, Pennsylvania, Linwood, Pennsylvania, Durham, North Carolina, and Lexington, Kentucky, and a total of 27.5 professional man-years is involved. In composition studies on smoke, including the development of improved analytical methods, 7.3 p.m.-y. are involved at Wyndmoor, Pennsylvania, and 3.1 p.m.-y. are under contract at the University of Kentucky. In similar studies on leaf, 3.0 p.m.-y. are involved at Wyndmoor, Pennsylvania, on a study of oxidation products of leaf and 2.0 p.m.-y. are under contract at the Research Triangle Institute, Durham, North Carolina for a study of the neutral resins of leaf. In studies on cigarette additives, 1.7 p.m.-y. are under contract at the Houdry Process and Chemical Company, Linwood, Pennsylvania, on the development of special additives and

1.0 p.m.-y. of Eastern Division personnel is involved at Lexington, Kentucky, under cooperative agreement with the University of Kentucky on the evaluation of the special additives and the development of other cigarette modifiers. Studies on pyrolytic products are being pursued with 1.2 p.m.-y. under contract at the University of Kentucky. A total of 8.2 p.m.-y. are involved under contracts at the University of Kentucky on bioassay studies. In addition, the Cigar Manufacturers' Association of America supports a research program on cigar smoke at Wyndmoor that is the equivalent of 2.0 p.m.-y.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

A modest program of research related to the utilization of tobacco is conducted by the stations. A number of studies on tobacco plant metabolism have been related to enzyme reactions and chemical intermediates produced during growth. Progress is being made toward identification of more than 150 compounds contained in the aromatic oil fraction of flue-cured tobacco. Development of analytical methods using gas chromatography and infrared spectra has contributed to this work. Formation of hydrocarbons in the leaf wax, photosynthetic production of glycolic acid in seedlings, and enzymic degradation of fatty acids during seed germination illustrate the variety of station research approaches to tobacco plant chemistry.

Compounds of great importance to tobacco curing are under investigation both as to source during growth and to fate during post-harvest processing. Plant tissue conversion of amino acids into polyphenols has been demonstrated, and the rule of oxidases to further catalyze the oxidation of polyphenols is continuing to unfold knowledge on the mechanisms of curing and aroma development. Investigations of machines to mechanize tobacco culture, harvest and curing are continuing. Basic engineering data on specific heat transfer characteristics of tobacco leaves have been determined for use in curing studies and have been applied as well to work on plastic mulches for weed control in seed beds. Study of agronomic practices is continuing. Control of sucker formation with herbicides such as maleic hydrazide is being evaluated. Nitrate nitrogen fertilizers have been reported important in upping U. S. type 41 cigar tobacco yields.

Market survey studies of U. S. cigarette brands is continuing to show that the percentages of different tobacco types remains virtually unchanged from year to year. Of the tobacco leaf components, flue-cured and oriental types increased only slightly. Usage of tobacco sheet (homogenized) has tended to increase and burley to decrease somewhat.

Fermentation studies on cigar tobacco are underway at Puerto Rico and other stations. Controlled modification of tobacco aroma is being explored via biochemical genetic approaches.

The tobacco program at the state stations involves 8.6 p.m.-y.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Composition of Tobacco Smoke.

1. Cigarette smoke. A study was made of certain of the published methods for determining benzo(a)pyrine in cigarette smoke. This compound is of major concern because of its potent cancer-producing properties. Of the methods studied, all were inadequate in respect to reproducibility and time required for the analysis. An improved method was then developed which gave more consistent results and reduced the analytical time by one-third. However, further improvement is necessary and work is continuing.

In work on the composition of cigarette smoke, crude fractionation of smoke condensate from 50,000 cigarettes showed that 25-30% of the condensate is water-soluble. Attempts to separate the water-soluble fraction by Sephadex gel filtration were unsuccessful, probably because a wide range of molecular weight substances is present. Comparative separations of the non-polar, water-insoluble neutrals of smoke showed that silicic acid is generally superior to alumina as an adsorbent for the initial stages of separation. The presence of a large number of olefinic structures, including neophytadiene, in the hydrocarbon fraction was confirmed. During the course of some of these separations, a study was made of the substances which codistill with ether from an ether-soluble, neutral fraction of smoke. At least five hydrocarbons (dipentene, styrene, o-xylene, toluene, and ethylbenzene), four carbonyls (acetaldehyde, isovaleraldehyde, α-methylbutyraldehyde, and n-propyl methyl ketone) and one ester (ethyl acetate) were tentatively identified. Of these, only α-methylbutyraldehyde was previously unreported in smoke.

It is anticipated that work on the composition of heterocyclic bases of smoke at the University of Kentucky will be initiated early in fiscal year 1966.

2. Cigar smoke. The hydrocarbons of cigar smoke were investigated extensively. Qualitative and quantitative similarities were observed between these findings and those previously published on cigarette smoke hydrocarbons. The following aromatic and related hydrocarbons were found in cigar smoke: benzene; toluene; ethylbenzene; m- and p-xylene; o-xylene and/or styrene; 1,2,4-trimethylbenzene; dipentene; and m- and/or p-ethyltoluene. Of these, the ethyltoluenes were previously unreported in tobacco smoke. Also, a series of aliphatic paraffins ranging from C_{13} to C_{25} were found in cigar smoke; these components have been reported previously in cigarette smoke.

B. Composition of Tobacco Leaf.

1. Oxidation products and related substances. Work has continued on the dark pigments of leaf which may be responsible for leaf color. Sephadex gel filtration has separated the whole pigment into a number of fractions with widely varying molecular weights. Of the fractions studied, all contained rutin, chlorogenic acid, and 20 amino acids, and some contained iron. Sugar analyses of hydrolysis mixtures indicated about 0.5 - 1.0 mole of rutin per 1300 g. of pigment. Attempts to obtain further information based on quinic acid

determinations and on separation of methylation products have failed thus far. Pyrolysis of the pigments has produced some interesting results (see below).

2. Neutral resins. Pilot experiments have been performed on the composition of the hexane-extractable neutral resins of leaf. The higher molecular weight substances showing carbonyl groups in the infrared spectra appear to be mainly esters which consist of acids having unsaturation but no aromaticity. Carbonyl compounds appear to be present in relatively small amounts and do not react readily with Girard's reagent. For the first time, a technique for separating non-polar substances by molecular weight ("gel permeation") was used, and two major groups of substances were isolated from the hexane and acetone solubles of leaf. The groups had average molecular weights of 723 and 1275, respectively. This technique promises to be of great value in separating lower molecular weight, known leaf components from the high molecular weight resins.

3. Volatile constituents. Final work on relationships between chemical composition and the organoleptic properties of leaf was completed. A system was developed for collecting the volatile substances of leaf which are emitted during leaf storage in a closed container. At least 35 components were found in the volatile mixture, of which tentative identifications were obtained on 17; included in the 17 were the following compounds previously unreported in tobacco leaf: n-pentane, n-hexane, n-heptane, benzene, toluene, three isomeric xylenes, n-caproaldehyde and methyl propionate.

C. Pyrolysis Studies.

The polyphenol-amino acid pigment discussed under Oxidation Products above was pyrolyzed at a temperature approximating that of a burning cigarette, i.e., 880°C. Most of the products were gases not condensable in dry ice traps. Evidence was obtained for the presence of at least 16 polynuclear aromatic compounds in the nonvolatile residue, including benzo(a)pyrene and dibenz(a,h)anthracene, both of which are potent cancer-producing substances known to be present in cigarette smoke. The yields of polynuclears appear to be quite high, e.g., about 10 milligrams of benzo(a)pyrene from 10 grams of pigment.

It is anticipated that pyrolysis studies to be conducted at the University of Kentucky will be initiated early in fiscal year 1966.

D. Cigarette Additives.

A system for measuring the coal temperature of cigarettes was developed. Values of about 875°C. were obtained which are comparable with the more reliable literature values. The claimed depression of the normal cigarette coal temperature by 50° - 100° C. using a type of hydrated alumina in cigarettes was confirmed. The effect of altering the pH of tobacco by adding citric acid or lime to cigarettes was studied. Citric acid imparts a light, mild flavor to the smoke; lime does not produce any striking changes in smoke flavor. With both citric acid and lime, an apparent increase occurred in the

benzo(a) pyrene content of the smoke compared to cigarettes without additives. However, the precision of the analytical method was not entirely satisfactory, and confirmation of this finding is needed.

E. Bioassay Studies.

It is anticipated that technical work in this area at the University of Kentucky will be initiated early in fiscal year 1966.

PUBLICATIONS AND PATENTS -- USDA AND COOPERATIVE PROGRAMS

Composition of Tobacco Smoke

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Osman, Stanley and Barson, J. 1964. The volatile bases of cigar smoke. Phytochemistry 3, 587-590.

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Schmeltz, Irwin, Stedman, R. L., Chamberlain, W. J., and Burdick, D. 1964. Composition studies on tobacco. XX. Bases of cigarette smoke. J. Sci. Food Agr. 15, 774-781.

Schmeltz, Irwin, Stedman, R. L., and Chamberlain, W. J. 1964. Improved method for the determination of benzo(a)pyrene in cigarette smoke condensate. Anal. Chem. 36, 2499-2500.

Stedman, R. L., Burdick, D., Chamberlain, W. J., and Schmeltz, I. 1964. Composition studies on tobacco. XVIII. Steam-volatile acids in smoke of cigarettes having different organoleptic properties. Tobacco Science 8, 79-81.

Stedman, R. L. and Stills, C. D. 1964. The flavor contribution of Turkish tobacco in blended cigarettes. U. S. Agricultural Research Service, ARS-73-43, 8 pp.

Stedman, Russell L. and Stills, Charles D. April 27, 1965. Turkish tobacco substitute for smoking tobacco. U. S. Patent 3,180,340.

General

Filipic, V. J. and Burdick, D. 1964. Polyethylene microcells for infrared analysis. Appl. Spectroscopy 18, 65-66.

Ogg, C. L. 1964. Determination of particulate matter and alkaloids (as nicotine) in cigarette smoke. J. Assoc. Offic. Agr. Chemists 47, 356-362.

Ogg, C. L. 1965. Report on tobacco. J. Assoc. Offic. Agr. Chemists 48, 105.

III. MARKETING AND ECONOMIC RESEARCH

MARKET QUALITY

Market Quality Research Division, ARS

Problem. Stored tobacco and tobacco products are subject to insect damage that seriously affects the grade, value, and potential end use. The price support program has resulted in a large buildup of stocks, some held for as long as 7 years, about twice the normal period for storage and aging. The long-term storage and the compact, dense structure of the tobacco as stored in hogsheads make insect control difficult. Repeated, heavy applications of fumigants or other control measures during extended storage has raised a question as to the extent and significance of residues that may be accumulated. Treatments applied during storage should be assessed further to be sure they are safe. Measures now used only hold insect populations in check and do little to reduce them or prevent them from becoming established. Attention should be given to the development of measures that will minimize or eliminate the use of chemicals, and at the same time eliminate or prevent infestations. To accomplish this it will be necessary to develop much more basic information than is now available on the ecology, physiology, and behavior of the insects that attack stored tobacco. Various fungi, bacteria, and viruses have ample opportunity to be associated with tobacco leaves. It is becoming quite apparent that the quantity of phenolic compounds is increased markedly in plant tissue, including tobacco leaf, diseased as a result of the activity of various pathogens. These substances may affect mammalian physiology. Quality research is needed to determine the changes that occur in the composition of tobacco leaf as the result of the metabolic activities of pathogens and to characterize the organisms that constitute the nonpathogenic microflora associated with tobacco leaves.

USDA PROGRAM

The Department has a continuing program headquartered at Richmond, Virginia, involving basic and applied research in entomology and chemistry, directed toward the insect problems of tobacco and tobacco products in the marketing channels. The research is conducted in cooperation with farmers' cooperative associations, industry groups, and the Agricultural Stabilization and Conservation Service of this Department. Two retirements and the inability to find qualified replacements has reduced the current Federal scientific effort on the prevention of insect infestation to 1 professional man-year. Some of the cross-commodity research at Savannah, Georgia, reported in Area 13, "Insect Control in Marketing Channels," also applies to the insect problems in stored tobacco.

The Department is conducting quality research under contract and cooperative agreement with the Agricultural Experiment Station of the University of Kentucky, Lexington, Kentucky.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Scientists of the State agricultural experiment stations are engaged in basic and applied research related to tobacco quality. Much attention is given to smoking quality determinations on varieties, and on tobacco subjected to a wide range of management practices. Other basic studies concern objective methods for determining smoking quality, the chemistry of curing, fermentation processes to provide specific types of tobacco leaf, and the measurement of physical properties.

Use of machines and machine methods in tobacco harvesting and handling is expanding. Research is directed to determining the effects of mechanization procedures on quality. The Puerto Rico station has a study on tobacco quality which is aimed at determining standards of quality in tobacco and correlating these with preferences of cigar smokers.

The total program involves 11.9 professional man-years for quality related research on tobacco.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Prevention of insect infestation

1. Nonpesticidal Control Methods. The tobacco moth was found to be extremely susceptible to the vacuum-steam flow process. It is considerably more sensitive than the cigarette beetle. All larvae and pupae of the tobacco moth were killed by this treatment in a 5-minute exposure at 120° F. A 25-minute exposure is required for a comparable kill of the cigarette beetle. A 1-minute exposure at 130° F. killed larvae and pupae of the tobacco moth. It requires 140° F. for the cigarette beetle. The eggs of the tobacco moth are more resistant to the treatment. (MQ 1-37)

2. Biology and Ecology. Tobacco moth larvae did not live more than 3 weeks at a relative humidity of 30 percent and temperatures of 70, 80, or 90° F. At 40 percent relative humidity a few larvae lived for 6 months but none pupated. Moths completed their life cycle at relative humidities of 50 or 60 percent at all three temperatures. The greatest emergence of adults was at the higher humidity, but was poor under all environmental conditions of the test. Larval development was more rapid at higher temperatures, but larvae became larger at the lower temperatures. (MQ 1-7)

3. Improved Pesticidal Control. Seventeen candidate compounds were evaluated in the laboratory for residual and vapor toxicity against the cigarette beetle. Two were sufficiently effective to warrant further investigation. A third compound was not quite as effective but will receive further attention because of its specificity, rapid loss of residual effect, and extremely low mammalian toxicity. None of the 17 compounds had much repellent or attractant effect. (MQ 1-35)

An experimental control procedure has been followed in 5 tobacco warehouses since 1962. It involves hydrogen cyanide fumigation early in the spring and dichlorvos aerosol applications twice a week during the active insect season. Not a single tobacco moth has been trapped in these warehouses since the program began. Cigarette beetles trapped in the 5 warehouses in the entire 1964 season totaled 2, 8, 23, 99, and 527. The latter warehouse contained old-crop tobacco. Control has been good to excellent, but there has been a slight increase each season in the number of beetles trapped in some of the warehouses.

In an effort to develop an even better program, a tobacco warehouse was fumigated with hydrogen cyanide and daily applications of dichlorvos aerosol have been made during the insect seasons. Only 11 cigarette beetles have been trapped in this warehouse since the beginning of the program. It is not certain whether they had developed in the warehouse or were chance migrants. Two more warehouses were added to this program in the spring of 1965 and no beetles had been trapped in either by August 1. (Unclassified)

4. Pesticide Residues. Dichlorvos was found only in trace amounts in tobacco from a warehouse where there had been an application of 0.5 gram of dichlorvos in aerosol form daily for 5.5 months. Samples for chemical analysis were taken from the perimeter of a hogshead directly beneath the dispersion pattern of the aerosol nozzle, where the residue would be expected to be the greatest. (MQ 1-33)

B. Quality maintenance

1. Effect of Post-Harvest Microflora on Tobacco Composition. Under contract and cooperative agreement with the Kentucky Agricultural Experiment Station, research has been initiated to identify the microorganisms that constitute the microflora associated with tobacco, to determine their life cycles, enzymatic capabilities, metabolite production and effect on composition of tobacco. (MQ 2-109)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Prevention of Insect Infestation

Childs, D. P. 1965. Effect on the cigarette beetle of flowing steam vapor under vacuum. Tobacco Science IX: 56-60, (Tobacco 160(14): 32-36). (MQ 1-37)

Childs, D. P., J. W. Mooney, and Tom Gentry. 1964. A mechanical method of retaining the cigarette beetle on a test surface. Jour. Econ. Ent. 57(6): 839-840. (MQ 1-35)

MARKETING FACILITIES, EQUIPMENT AND METHODS

Transportation and Facilities Research Division, ARS

Problem. Differences in varieties of individual field crops and in the environments of producing areas where they are conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, and storing of these crops and to maintaining their quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of commodities into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA PROGRAM

The Department has a long-term program involving engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Studies on the handling of tobacco on sales floors are conducted at Raleigh, N. C., in cooperation with the North Carolina Agricultural Experiment Station and selected warehouses.

The Federal effort devoted to tobacco research in this area during the fiscal year 1965 totaled 0.5 professional man-years.

REPORT OF PROGRESS OF USDA AND COOPERATIVE PROGRAMS

Handling Tobacco in Warehouses

At Raleigh, N. C., research was initiated in December 1965 to improve work methods, techniques, operating procedures, layouts, and equipment for handling tobacco in warehouses (sales floors).

Observations on the marketing of tobacco were made in the burley tobacco area of the United States and in the flue-cured tobacco area of Canada. Information was obtained on the method of lighting sales floors, types of handling equipment used, and selling methods employed.

An experimental tobacco handling system, to be used in the study on handling tobacco on warehouse floors, was developed and equipment ordered. Equipment was selected to permit flexible arrangement of the components to permit the study of a variety of system layouts. Main components of the system include a gravity conveyor, auction room, grading room, and industrial forklift trucks.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

None

ORGANIZATION AND PERFORMANCE OF MARKETS

Marketing Economics Research Division, ERS

Problem. Economic research in agricultural marketing revolves around the problems of increasing efficiency in the processing and distribution system and providing a foundation for orderly adjustments to changes inside and outside of agriculture. Marketing must be looked upon as a dynamic and changing process. The capacity to adjust to and cope with the dynamics of modern marketing is required increasingly of producers and distributors of farm products. Demands of a more knowledgeable and sophisticated consuming public are adding to the pressures for an even more rapid escalation of developments and changes within the marketing system. Changes in institutions and redirection of public policies and programs are modifying the economic environment in which marketing firms must perform and operate. Because of rapid changes and increasing complexities associated with a dynamic marketing system, it is necessary that a continuous program of research be conducted in marketing--a program aimed at keeping producers and marketing firms abreast of the flow of events and providing information necessary to them in making proper and orderly adjustments to change.

Research in the area of organization and performance of markets is designed to find solutions to economic problems of marketing, including the transportation of farm products. This involves economic studies of: size, ownership, financing, structure and practices of marketing firms; measurement of farm-retail spreads; cost of marketing and allocation of costs and charges among agencies and functions; resources used in marketing; measurements of growth and labor productivity; demand for and supply of food marketing services; pricing of products and services; interregional competition; and farmers' bargaining power. Economic studies of transporting farm products include: Determining patterns of product flow that will maximize returns to farmers and minimize costs to consumers while taking into account the needs of carriers, factors affecting carrier costs and charges for moving farm products and supplies, impact of technological changes in transportation services and facilities upon product flows and optimum locations of processing facilities, industries, etc.

Such studies furnish a basis for adjusting to change and keeping abreast of technological and scientific developments. Likewise, the studies provide a sound basis for both private and public policy decisions as they relate to marketing.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program of economic research designed to increase the efficiency of marketing and assist producers and marketing agencies in adapting to a changing environment. In fiscal year 1965, 0.6 professional man-year was devoted to research on market institutions and market power, and 1.5 professional man-years were devoted to studies on tobacco prices, margins, and costs.

PROGRAM OF STATE EXPERIMENT STATIONS

Market Institutions and Market Power

Changes in the structure of marketing agricultural products affects the bargaining power of buyers and sellers. These changes also affect marketing practices, services, and prices--and ultimately producers, marketing firms, and consumers. Research underway at the State stations deals with these changes and some possible alternatives.

Two stations each have tobacco projects. One deals with the existing market structure, historical supply-demand relationships, and possibilities for price improvement; the other describes the organization and operation of tobacco auction warehouses. It involves a total of 1.9 professional man-years at the State experiment stations.

Another station is studying factors affecting labor requirements in market preparation of flue-cured tobacco. A total of 0.7 professional man-year is involved.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Market Institutions and Market Power

The structure of markets for agricultural products is changing in many dimensions and the market power of buyers and sellers and practices of marketing firms are shifting in response. All these changes have significant impacts on farmers, consumers, and marketing agencies. The Marketing Economics Division conducts studies on many phases of this changing market.

The tobacco auction warehouse system has remained relatively stable for a number of years. This institutional stability has made it difficult to minimize cost by planning the optimum size operation. An analysis of burley auction warehouses in Kentucky revealed wide variations in floor labor required per thousand pounds of tobacco sold. The tobacco auction system in Canada is able to handle tobacco for less than one-third of the costs of a typical auction warehouse in the United States.

B. Prices, Margins, and Costs

In the last decade, prices to consumers for most products of farm origin have risen despite downward trends in farm prices. This widening of farm-retail spreads has brought widespread public concern about the efficiency and performance of the marketing system which culminated in the establishment of a National Commission on Food Marketing.

The farmer's share of the consumer's cigarette dollars has been declining since 1947. In 1964 the farmer's share for cigarettes was 9 percent compared with 14 percent in 1947. This decline is attributed mainly to a decrease in the per unit tobacco requirements and a failure of farm prices to rise in proportion to the rise in marketing charges and taxes. The lower tobacco

requirements are due to the increased popularity of filter-tip cigarettes and advanced technology in the manufacturing segment of the industry. Technological advances have not been confined to the manufacture of cigarettes. Cigar manufacturers have obtained some labor reductions in the manufacturing process with the development of homogenized binders and the shift to short-filler cigars. The number of cigar machine operators decreased by 43 percent from 1955 to 1961, while cigar production increased by about 15 percent.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

None.

ECONOMIC AND STATISTICAL ANALYSIS

Economic and Statistical Analysis Division, ERS

Problem. Because supply and demand factors for tobacco and tobacco products are changing continuously, these factors must be regularly appraised and these appraisals disseminated to farmers, the trade, and other interested persons. The typical tobacco farmer cannot afford to collect and analyze the statistical and economic information that vitally affects his economic position. Economic facts and analyses must be provided on supplies, prices, production and consumption of tobacco and tobacco products, and the export-import trade. Proposals to modify existing tobacco programs must be analyzed to assist the evaluations of alternatives by advinistrators and Congress. In addition to the usual economic variables, analyses have to take into consideration the health-related aspects as they may pertain to consumption of tobacco products and utilization of tobacco leaf.

USDA AND COOPERATIVE PROGRAM

A. Commodity Situation and Outlook Analysis

The program includes a continuous appraisal of the current and prospective economic situation of tobacco. These appraisals, developments of interest to the industry, and results of special studies are published four to six times a year in the various commodity Situation reports, with brief resumes in the quarterly Demand and Price Situation, and when appropriate in monthly issues of the Farm Index and the Agricultural Outlook Digest. Comprehensive analyses of the current and prospective situation are presented at the Annual Outlook Conference, and more limited appraisals given at regional and State conferences and at meetings with industry groups. Special analyses are prepared from time to time on the probable effect of proposed programs on the supply, price, and utilization of the various commodities. Basic statistical series are developed, maintained, improved, and published for general use in statistical and economic analysis.

A total of 1.5 professional man-years were devoted to research on this program in fiscal year 1965.

B. Supply, Demand and Price of Agricultural Commodities

The program of basic research into the factors affecting prices, supply, and consumption of principal agricultural commodities is concerned with four broad areas: (1) Measurement of consumer response to price, income, and other factors; (2) measurement of producer response to price and other factors; (3) measurement of the effect of supply and demand factors on prices to farmers and to consumers; and (4) improvement of statistical techniques for measuring agricultural economic relationships and for the development of statistical formulas which can be used in making price, supply, and consumption forecasts and in appraising economic implications of alternative programs.

Changes in emphasis are made from time to time to utilize effectively the professional skills available and to adjust to work having the highest priority. The research on tobacco is related to economic effects of technological changes including information relating to health on supply, demand, utilization, and price of leaf tobacco.

A facet that is becoming increasingly important in carrying out the statistical and econometric work of the Division is the use of electronic computers. The program includes continual evaluation of latest developments in the field, equipment and computer programs available for use, and the application of this to our data submitted for machine processing.

The USDA program of research in this area involves 9 professional man-years and is located in Washington, D. C. Of this total, 0.5 professional man-year is devoted to tobacco research.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part, the States depend on the U. S. Department of Agriculture for the yearly across-the-board commodity situation and outlook research. There is increasing interest in longer range price prediction because of the growing specialization of farms, which makes yearly enterprise shifts less common and less feasible, and which calls for large capital commitments over longer periods of time. The State extension staff members supplement and adapt such research information to meet the commodity situation of their States.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Commodity Situation and Outlook Analysis

Special attention was devoted to a number of problem areas. Intensive analyses of yield data and the economic effects of proposed program changes were made in connection with acreage-poundage legislation. Sample county data were analyzed and results projected to State and national totals to provide the necessary guidance for Department administrators and Congressional groups in framing legislation. The tobacco consumption pattern was and is being closely followed in light of the smoking-health issue. Cigarette consumption has regained much of the ground lost after publication of the Surgeon General's report on smoking and health in January 1964, but continuing appraisal of the consumption pattern is necessary in view of the cigarette labeling regulation and the increasing educational-informational programs being launched. Proposed legislation bearing on cigarette smoking and health was analyzed. A study also was made of alternative programs to make U. S. tobacco exports more competitive.

B. Supply, Demand and Price of Agricultural Commodities

Analysis was made of price relationships and relationships of stocks among the various types of flue-cured tobacco. Continuing analysis was made of trends in utilization of tobacco as affected by recent technological changes,

and their impact on growers. In 1964, use of tobacco in cigarettes is estimated to have declined about 3 percent, whereas cigarette output declined about 2 percent. The impact and implications of the smoking-health issue during the past decade and in the recent period were studied and the 1964 declines in cigarette consumption by States were measured on a per capita (18 years and over) basis. Further discussions were held with Public Health

Service personnel regarding that agency's forthcoming survey data on tobacco use and consumer attitudes, and some preliminary results obtained. Additional analysis was made of alternative methods of supply adjustment.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Conover, A. G. and Sackrin, S. M. Tobacco Situation. Published quarterly. ERS, USDA, Washington, D. C.

Conover, A. G. November 1964. The Tobacco Situation--Record 1964-65 Supplies. Agricultural Situation, pp. 1-2.

Conover, A. G. February 1965. The Tobacco Situation--1964 Breaks Long Uptrend. Agricultural Situation, pp. 6-7.

Conover, A. G. June 1965. New tobacco program approved by referendum. Agricultural Situation, pp. 13.

Conover, A. G. July 1965. The Domestic Consumption of Tobacco Products and the Smoking-Health Issue. Paper presented at the Twentieth Tobacco Workers Conference. University of Kentucky, Lexington, Kentucky. 17 pp.

Sackrin, S. M. May 1965. Tobacco acreage smallest in many years. Agricultural Situation, pp. 10-11.